2000

Electromyographic Analysis of Trunk Musculature following a Nine Hole Round of Golf: The Fatigue Factor

Katie Glessing
University of North Dakota

ELECTROMYOGRAPHIC ANALYSIS OF TRUNK MUSCULATURE FOLLOWING A NINE HOLE ROUND OF GOLF: THE FATIGUE FACTOR

by

Katie Glessing
Bachelor of Science in Physical Therapy
University of North Dakota, 1999

An Independent Study

Submitted to the Graduate Faculty of the

Department of Physical Therapy

School of Medicine

University of North Dakota

in partial fulfillment of the requirements

for the degree of

Master of Physical Therapy

Grand Forks, North Dakota
May
2000

This Independent Study, submitted by Katie Glessing in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)

PERMISSION

Title	Electromyographic Analysis of the Trunk Musculature Following a Nine Hole Round of Golf: The Fatigue Factor
Department	Physical Therapy
Degree	Master of Physical Therapy

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Signature [illegible]

Date 12-13-99

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ACKNOWLEDGEMENTS

There are a few people I would like to thank for making this study possible. First of all, my parents, their love and support, lots and lots of support have been invaluable. I would also like to thank Michelle Ballan, Nicole Garret, and Christine Wellner, my partners during this study. Their help and their abilities to make me laugh at just the right times have made doing this study a much more enjoyable experience. Thanks also goes out to anyone else who has helped me out along the way (Jim especially, for the formatting assistance). And last, but not least, a huge thank you to Dave Relling. He went far beyond the call of duty to help us with this study. Without his help and hard work I would probably still be sitting in the library trying to finish this study.

ABSTRACT

The purpose of this study is to determine the fatigue component in trunk musculature following a simulated nine hole round of golf through analysis of the trunk muscles during the golf swing.

Our subjects consisted of 4 males ages 22-26. Each subject performed 5 EMG monitored golf swings with a driver prior to and following a simulated 9 hole round of golf. This provided pre-round and post-round data to analyze and determine if significant fatigue occurred in the trunk musculature.

The results showed that a significant shift in median frequency occurred, signifying muscle fatigue, in 2 of the 4 subjects when all muscles were analyzed collectively. When individual muscles were analyzed each muscle experienced a significant shift in median frequency except the left abdominal oblique. The swing times for each subject were also analyzed and compared. The 2 subjects who fatigued demonstrated faster swing times suggesting a possible relationship between speed of the golf swing in increased muscle force output and increased muscle fatigue. These results will attempt to provide information on establishing training and conditioning programs targeting the trunk musculature. These programs can be developed to increase muscle endurance and decrease the likelihood of faulty swing mechanics and injury.

CHAPTER I

INTRODUCTION

Golf has become an increasingly popular sport for men and women of all ages around the world. Golf is reportedly practiced by up to 10-20% of the overall world's adult population.[1] Because of golf's increasing popularity there has been an equal increase in reports of golf related injuries. Relatively few studies have been performed to research what is causing these injuries.

Problem Statement

There are an increasing number of amateur golfers today with the most commonly reported injury being low back pain. Injuries are most likely to occur during the golf swing. It is thought that trunk muscle fatigue can lead to improper body mechanics and result in possible injury. However, relatively little research has been done to identify if fatigue actually occurs in trunk musculature during a round of golf.

Purpose

The purpose of this study is to determine if fatigue occurs in trunk musculature following a simulated nine hole round of golf through the EMG analysis of the golf swing. Analyzing muscle fatigue within the trunk musculature is essential in identifying fatigue as an injury risk factor. It is the significant shift in the median frequency that provides the determinant of muscle fatigue in EMG studies.

Significance

This study is important for the profession of physical therapy by providing information concerning the role muscle fatigue has in the game of golf. By determining whether fatigue is experienced by trunk musculature and identifying which muscles do fatigue, training and conditioning programs can be developed to increase muscle endurance. Increasing endurance may lead to a decrease in the likelihood of muscle compensation patterns during the golf swing, which often results in faulty swing mechanics and an increased risk of injury.

Research Question

Is there a significant median frequency shift in trunk musculature after a simulated nine hole round of golf?

Null Hypotheses

There is no significant difference median frequency shift in trunk musculature after a simulated nine hole round of golf.

CHAPTER II

LITERATURE REVIEW

Golf has become an increasingly popular sport throughout the world. It is practiced by 10-20% of the overall adult world's population, attracting people of all ages, gender, and socioeconomic status.[1] Reports have revealed that there are nearly 25 million golfers in the US, ranking golf tenth in terms of participation according to Stephens and Craig in 1988.

Golf is unique compared to other sports in that it can be enjoyed throughout one's lifetime, therefore the number of participants of advanced years is significant. The National Golf Foundation in the US reports that greatest increase in participation was by those 50-59 years of age. These golfers greater than 50 years old accounted for more than 25% of golfers in the US, yet were responsible for more than 50 % of rounds played.[1, 2]

Epidemiology

Golf's increase in popularity has also led to an increase in golf-related injuries. Few studies have reported on the prevalence and overall ranking of golf injuries, partly due to the belief that golf is a minimal risk sport. However, injuries do occur during golf, in the professional and amateur ranks. McCarroll et al[2] reported that in a study of 1,144 golfers the overall prevalence of injury was 62%. They also found that players with a lower handicap (1-9) and older than 50 years of age had a higher prevalence of injury.

Batt et al[1] reported a prevalence of 32% of players injured while golfing. Thierault et al[2] showed 25.2% injured for male and 29% for female golfers from a survey of 600 amateurs. Those 3 studies also revealed similar injury rates per golfer, 1.28, 1.19, and 1.31 respectively in their cohorts.

Biomechanics Of The Golf Swing

The swing represents the phase during which there's the greatest demand, biomechanically, on all involved musculoskeletal structures. Since hitting the ball is repeated an average of 50 times during an 18 hole course, it's easy to see how injuries can occur either through overuse or actions causing severe trauma.[1]

There are 4 components to the golf swing: 1. set-up 2. back-swing 3. forward swing through impact 4. follow-through. EMG analysis reveals a high level of trunk muscle activity during these phases (see Table 1). Electromyography reveals during the inital twisting of the trunk or back swing the left external oblique, left rectus abdominus, and left paraspinals are active. During forward swing through impact the right side trunk muscles (external obliques and abdominals) are most active, along with both right and left paraspinals, which act to stabilize the trunk. Finally, during follow through the anterior trunk muscles are primarily active.[1, 2, 3, 4, 5]

The trunk rotations achieved by this muscular activity is the most important lever for achieving maximum speed during the golf swing. Pink et al[4] reported players who are less technically skilled or who are older have up to 50% less trunk rotational capacity than younger or better technically skilled individuals. Those who are less technically skilled or older must compensate with greater muscle activity to hit the ball as far as possible. As a result, flexibility, strength, and articular stability of the trunk and spinal structures may be considered as potentially the most restrictive variables for performance and therefore important determinants for risk of injures.[2, 3]

Table 2.1. Summary of Most Active Trunk Muscles During the Three Active Phases of the Golf Swing according to EMG Data[1, 2, 3, 4, 5]

	Back Swing	Forward Swing-Impact	Follow Through
Left External Oblique	X	X	
Right External Oblique		X	X
Left RectusAbdominus	X		X
Right RectusAbdominus		X	X
Left Erector Spinae	X	X	
Right Erector Spinae		X	
Left Gluteal	X		X
Right Gluteal		X	

Etiology

Mainly golfing injuries occur from a combination of factors including: overuse, poor technique, and lack of a specific pre-game warm-up. The majority of problems occur from soft tissue musculoskeletal injuries, principally overuse. Overuse is the number one injury of professionals and number two of amateurs. Most of the injuries are localized to the back, wrist, elbow, and shoulder. In a study of 412 golfers by Jobe and Yocum, back pain was the most commonly reported site of injury. In addition, McCaroll et al[1] reported in a cohort of 1,144 amateur golfers, low back pain was the most common injury reported. In both these studies over practice, excess play, and poor swing mechanics were the most common direct cause of overuse injuries.

The number two cause of injury in professional golfers and number one cause of injury of amateur golfers is poor technique, particularly in swing mechanics.[2] According to Batt the period of the game where injury is most likely to occur is during the swing phase. Batt also reports amateurs have increased variability in their golf swings. This increased inconsistency of swing may be exacerbated by stress, which produces variable and generally increased muscle tone. As a result amateurs produce greater spinal torque and lateral bending forces during their golf swing, which with repetition, may cause or exacerbate back problems. When trunk rotation during the golf swing is decreased as in those with less skill or the aged, because of decreased joint flexibility or existing dorsolumbar disease, swing performance will be reached only through dorsolumbar and abdominal overload. This leads to muscular fatigue, muscular compensation, and ultimately injuries. In a study by Theirault et al[2] of amateur golfers it was reported that injured golfers showed significant trends for playing increased games per week, taking fewer lessons, and expressed an increased index of tiredness after a day of golfing versus the non-injured. Theirault concluded an appropriate level of physical fitness, in addition to practice, could help reduce injury in amateur golfers.

The third cause of golf injury for both professionals and amateurs is lack of a specific pre-game warm-up program. Loads and muscle activity may predispose a golfer to muscle strains, herniated discs, spondyloses, facet arthropathy, and/or spinal stenosis. By stressing the importance of a warm-up and an off-course stretching and strengthening program these injuries may be decreased.

Dorsolumbar Injuries

Forces are applied to the dorsolumbar region during the golf swing in 4 distinct directions: 1. lateral flexion 2. anterior-posterior traction 3. rotation 4. compression. The amateur golfer presents with increased lateral flexion, anterior-posterior traction, and rotation when compared to the professional golfer. These forces cause damage to the paraspinal muscles, intervertebral discs, vertebral ligaments, facet joints, and spondyloses. Disc degeneration, in older players especially, will limit cushion and the capacity for trunk rotation, thus decreasing the power of the swing. This may also make other spinal components more vulnerable to injury and prone to chronic discomfort.[2]

These ailments may be clinically improved by rest, anti-inflammatories, physical therapies, and a good low back rehab program, designed to regain maximum flexibility and strength.

Injury Prevention

Identifying and correcting technical errors associated with a biomechanically deficient golf swing is an important first step that should be taken to significantly decrease golf injuries.[1, 2, 3] Physical conditioning, according to Theirault, is undoubtedly the second most important injury prevention factor for both professionals and amateurs. Good physical condition allows for prolonged golf practice throughout the year without harm and helps prevent overuse injuries.

This conditioning should include: short pre-game warm-up, stretches for the hands, wrists, forearms, elbows, shoulders, cervical spine, pelvis, and lower spine, a series of golf swings, gradually increasing in range of motion and rigor, and a 10-15 minute walk.[1, 6, 7]

Overall, few studies have been performed to measure the benefits of a pre-game warm-up and physical conditioning on injury prevention. However, golfers who tend to perform a similar program report feeling an increase in swing coordination, efficiency, and record better scores. A study of 160 regular golfers who consistently performed a pre-game warm-up had less golf injuries as compared to those who did not perform a warm-up.[1, 2, 3]

Long-term pre-season conditioning is also essential for injury prevention. This type of program should focus on enhancing flexibility, muscle strength, and endurance of the main functional body segments involved in the golf swing.[2] Attention should also be paid to cardiovascular conditioning. Continuous heart rate monitoring of 5 golfers during an 18 hole round of golf revealed an average heart rate of 108 beats per minute. For many aerobically unconditioned individuals, maintaining this level of activity continuously for 4-5 hours may gradually hamper their golf performance, induce metabolic fatigue, and possibly increase risk of injury. A light to moderate pre-season aerobic conditioning program (walking, biking, etc.) could enhance golf performance over an entire day of golfing, resulting in less fatigue and fewer injuries.[2]

As alluded to in the above information, fatigue may play a role in the risk of injury for a golfer, professional or amateur. However, the lack of prior research on the prevalence of fatigue during a nine hole round of golf, leads us to the purpose of our study. Determining if there is a significant amount of fatigue in the trunk musculature during a nine hole round of golf.

CHAPTER III

METHODOLOGY

This project was reviewed and approved by the University of North Dakota Institutional Review Board prior to the initiation of the study (See Appendix A).

Subjects

The voluntary participants in this study were four adult males who met all participation guidelines: negative history of low back injury, male, age 18-30, and an average score of 45 strokes during a nine hole round of golf. All subjects were UND students. The purpose and procedures of the study were explained to each participant. Each subject read and signed a statement of informed consent prior to participation.

Instrumentation

Self-adhesive pre-gelled silver/silver chloride EMG surface electrodes (Multi Bio Sensors, El Paso, TX, 79913) were placed on the subjects to record EMG activity. The analog EMG data was collected with the Noraxon Norswitch and Noraxon Telemyo8 telemetry transmitter (Noraxon USA, 13430 N. Scottsdale Rd., Scottsdale, AZ, 85254). This data was transmitted via telemetry to the Noraxon receiver. The analog data was converted to a digital signal with a 16 bit A/D PC card. A data sampling rate of 1,000 Hz (PCM-DAS 16S/16, Computer Boards, Inc, Mansfield, MA, 02048) was used for this conversion. The data was then stored on an IBM compatible PC utilizing a Pentium processor. An Infrared Retro-Reflective A.C./D.C. Photo-Electric Sensor Number NX5-

RM7B, (Sunx, 1207 Maple St., West Des Moines, IA, 50265) was placed between the subjects legs on the floor with the reflector perpendicular to the subject 5 feet away. A reusable footswitch (Noraxon USA, 13430 N. Scottsdale Rd., Scottsdale, AZ, 85254) was placed over the plantar surface of the right mid-heel and secured by athletic tape.

Procedure

Subjects were tested independently at the University of North Dakota Physical Therapy Department in Grand Forks, ND. Prior to initiation of the study, EMG equipment was pre-tested by the researchers to ensure proper signal transmission and reception. The procedure and purpose of the study were explained to the subjects prior to individual testing. Each participant signed a statement of informed consent.

The subjects were dressed in a t-shirt and athletic shorts. Electrode sites were prepared by shaving excess hair from the area followed by scrubbing the sites with rubbing alcohol to aid in signal conduction. Surface electrodes were placed bilaterally over predetermined motor points. The motor points were marked as follows (See Figure 3.1): 1) gluteus maximus muscles at the midpoint of a line running from the inferior lateral angle of the sacrum to the greater trochanter, 2) the abdominal oblique muscles 5 cm superior to the ASIS, 3) the erector spinae muscles horizontally aligned with the L_3-L_4 interspace, 4 cm lateral to the midline.[8] A ground electrode was placed over the ASIS. Leads from the electrodes and footswitch were connected to respective transmitters. The transmitters were secured to the subject's right thigh using an adjustable belt in order to avoid interference of the golf swing. Subjects performed maximum manual muscle tests bilaterally for each muscle to establish a maximum voluntary contraction for further

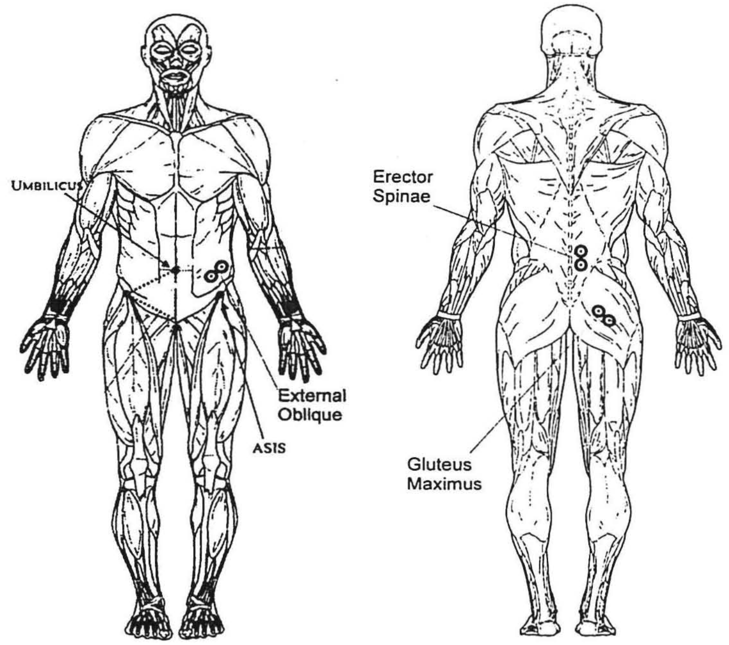

FIGURE 3.2. Electrode placement for golf swing analysis.

analysis. The MMT was used to normalize EMG data allowing comparison and statistical analysis across subjects for particular trials.[6]

Subjects were instructed to address the ball with the right heel elevated, but as relaxed as possible in a vertical posture. The club head was positioned forward of the infrared light beam set up between the subjects feet. Data collection began when minimal EMG muscle activity appeared, the subject then lowered the right heel to the floor, triggering the foot switch, and assumed a natural swing posture to begin the pre-contact phase of the swing. The light beam was broken on take-away and used as the first event marker signaling the start of the swing. The subject proceeded to complete a normal golf swing. After follow-through, the swing was concluded with the subject returning to the beginning position with both heels on the ground. During the swing, the lifting of the right heel was the second event marker signaling contact of the club with the ball. The return of the right heel to the floor signaled the end of the swing. The subjects were allowed 2-3 warm-up swings to become comfortable with the equipment and swing procedure.

Each subject then performed five swings with a driver hitting a foam practice ball from a rubber tee into a practice net to obtain pre-round EMG data. The subject was then disconnected from the EMG receiver and accompanied by two researchers to a practice field about 500 yards from the testing area. The subject performed a repeated sequence of golf swings with a maximum of 45 total strokes to simulate a nine hole round of golf (Table 3.1).

Table 3.1 Sequence of Simulated 9 Hole Round of Golf

Club	Number of Swings/Hole
Driver	1
5 Iron	2
Putter	2

The subject and researchers returned to the testing area and began EMG data collection as previously described within five minutes of finishing the simulated round. Each subject performed five swings in the same manner as before the simulated round to obtain the final post-round data.

Data Analysis

The raw EMG data was analyzed with the MyoResearch 97 software package (Noraxon USA, 13430 N. Scottsdale Rd., Scottsdale, AZ, 85254). Each individual trial was displayed and event markers were placed where the light beam was disrupted (marker A), when the heel switch was de-activated (marker B), and when the heel switch was reactivated (marker C)

Swing Time

The time of swing was determined by reading the chronological time between markers A and C. No attempt was made to control or normalize time of swing across subjects.

EMG

All subjects performed maximal voluntary contractions (MVC) with a five-second hold prior to initiating the pre-round swings. The raw EMG output for the MVC was rectified for each individual muscle group (Gluteus Maximus, Abdominal Obliques, and Erector Spinae). The maximal 1000 points (1 second of data) of the MVC was used for normalizing the rectified EMG in subsequent phases of the experiment. Each subject then performed 5 pre-round and 5 post-round swings. The raw EMG for each of the trials was rectified and then normalized to the MVC of the appropriate muscle group. All trials were combined to form an ensemble average for the pre-round and post-round golf swings (See Figures 3.2 and 3.3).

Median Frequency

The digitized raw EMG data from marker A to marker C was used to determine median frequency. The EMG output was processed through Fast Fourier Transformation (FFT) using the MyoResearch 97 software. The median frequency was determined for the period of time from marker A to marker C. A shift toward a lower median frequency was operationally defined as representing muscle fatigue.

Statistical Analysis

The main effects of a two-way analysis of variance (ANOVA) (Subject X Swing Time) on change in median frequency was performed at the p=.05 significance level. This was followed by a Scheffe post-hoc analysis of the results.

The paired t-test was used to analyze the median frequency shift occurring between pre-round and post-round trials. Paired t-tests were performed for all subjects and all muscles, as a group and individually (all subjects, all muscles Pre vs Post; individual subject #1,2,3,4, all muscles Pre vs Post; individual muscle #1,2,3,4,5,6, individual subject #1,2,3,4). A significance level of p=.05 was used to determine significance during these tests. The normalized muscle activity was not tested for statistical significance.

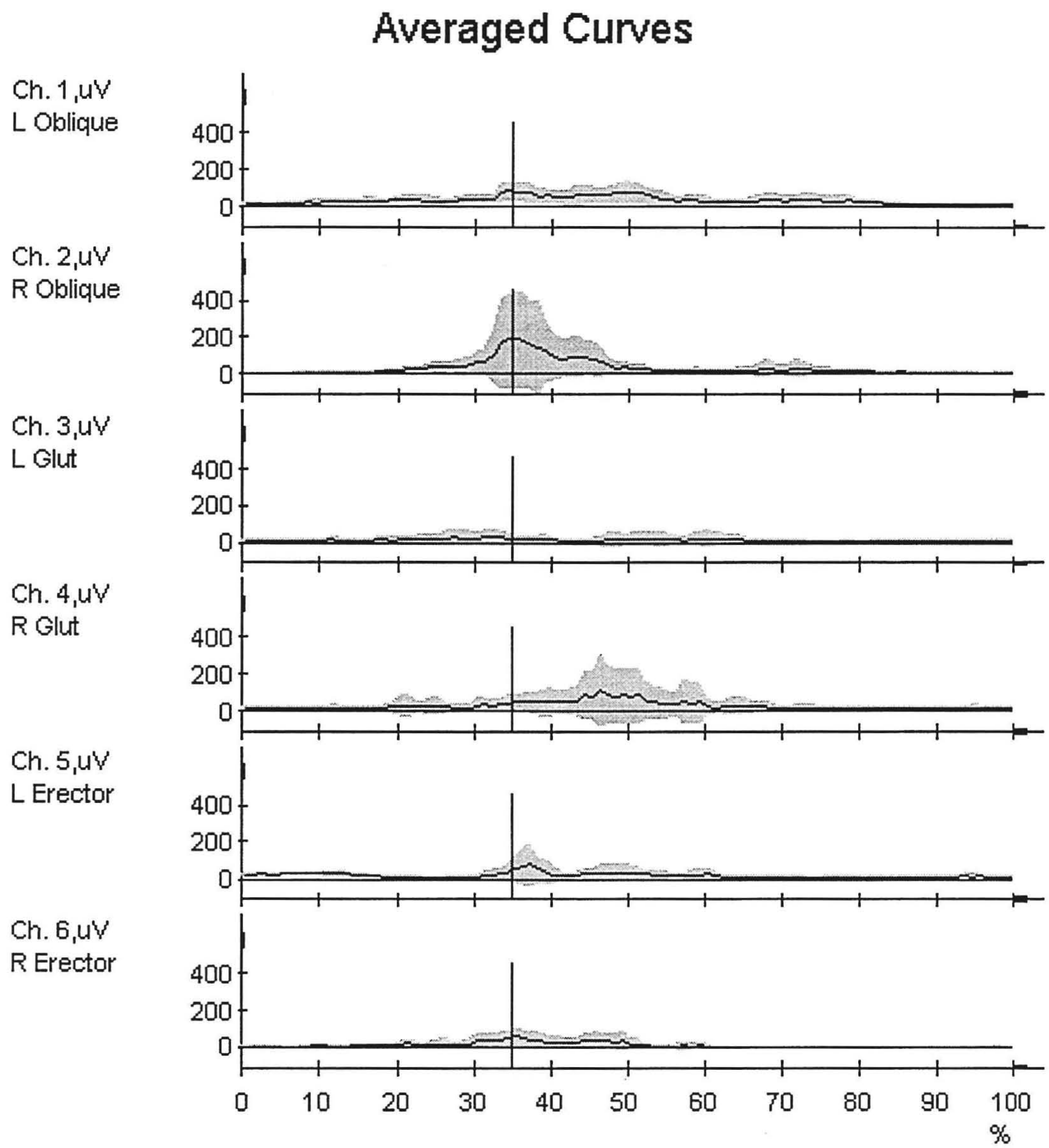

FIGURE 3.2. Ensemble average pre-round golf swing.

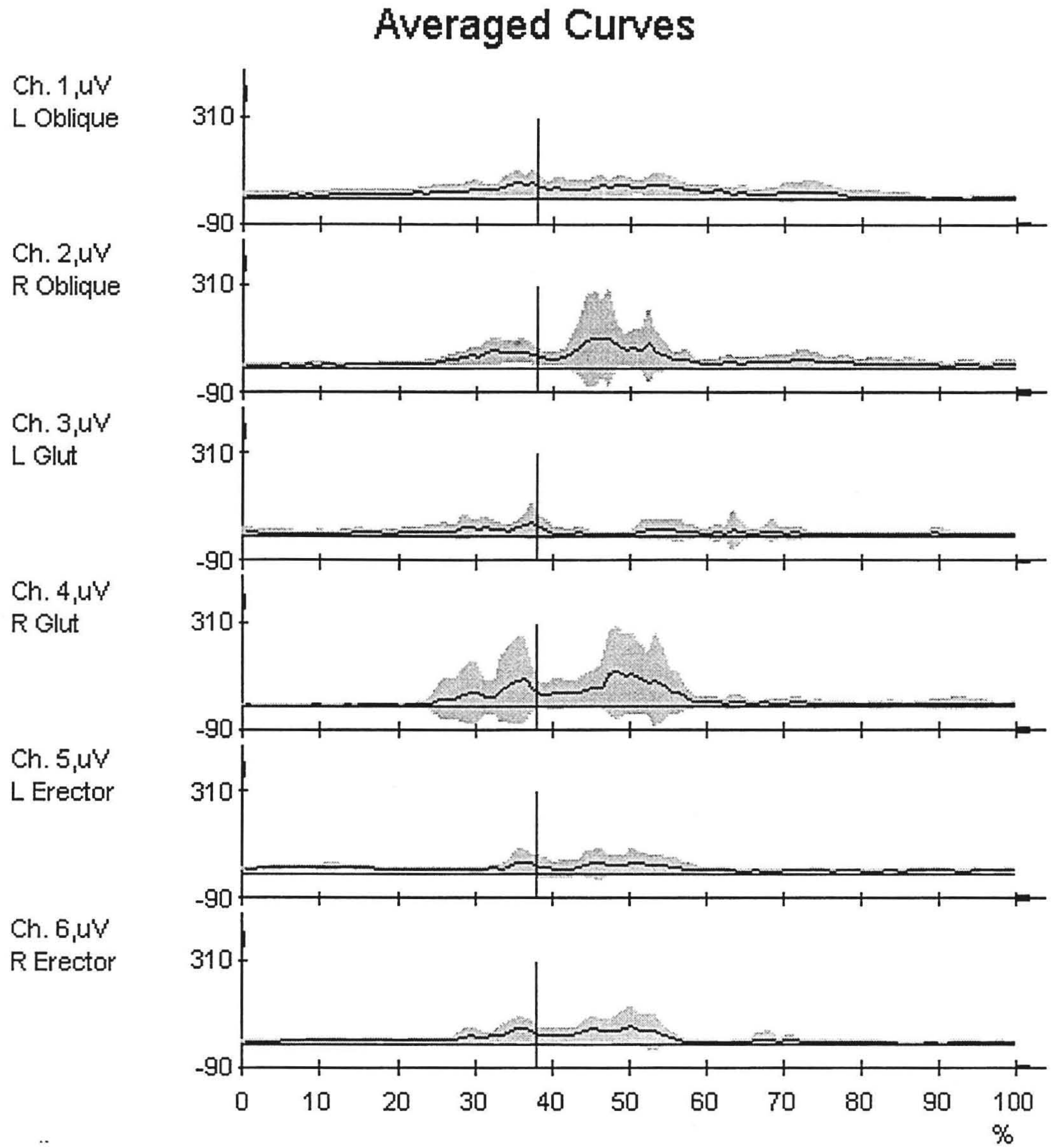

FIGURE 3.3. Ensemble average post-round golf swing.

CHAPTER IV

RESULTS

Subjects

The subject group consisted of four adult males with an age range of 22-26 years old (mean age=24), average weight 173.75lbs. and average height 72in. There was a zero drop out rate for the study. Average golfing ability was 45 (SD= ± 5) strokes per nine holes of golf.

EMG

The results of the EMG data were used to determine if there was a significant MF shift in the following: 1) all subjects, all muscles Pre vs Post round, 2) all muscles, individual subjects Pre vs Post round, 3) individual muscles, all subjects Pre vs Post round.

All four subjects were looked at collectively to determine if there was a significant shift in MF of all six muscles grouped together between pre-round and post-round data. A paired t-test found a significant shift in MF ($p<.001$). All subjects collectively and each muscle were also looked at for significance. A paired t-test found a significant shift in MF for the right abdominal oblique ($p=.025$), left gluteus maximus ($p=.008$), right gluteus maximus ($p=.007$), left erector spinae ($p=.017$), and right erector spinae ($p=.016$). The left abdominal oblique showed no significant shift in MF ($p=.773$) in a paired t-test. When looking at each subject individually with relation to all muscles together a paired t-test showed subjects 2 and 3 displayed a significant shift in MF (p_2=.002, p_3<.001). Subjects 1 and 4 showed no significant shift in MF with a paired t-test (p_1=.051, p_4=.073)(See Appendix B).

Swing Time

A two way ANOVA main effects only demonstrated significant difference between subject's swing times. There was, however, no significant difference within a subject's swing times when comparing before and after the simulated nine hole round of golf (See Table 4.1). Mean swing times for subjects 1,2,3 and 4 were 3.938s, 2.300s, 3.109s, and 4.212s respectively. Post hoc analysis between subjects revealed a significant difference in swing times between subjects 1-2, 2-4, and 3-4 (See Table 4.2).

Table 4.1: Two Way ANOVA Tests of Between-Subject Effects

Dependent Variable: Time

Source	Type III Sum of Squares	df	Mean Square	F	Significance
Subject	19.344	3	6.448	14.683	.000
Swing	6.233E-04	1	6.233E-04	.001	.970
Error	12.296	28	.439		

Table 4.2: Scheffe's Post Hoc Analysis of Swing Time Among Subjects

Dependent Variable: Time

Subject	Subject	Mean Difference	Standard Error	Significance	95%Confidence Lower Bound	Interval Upper Bound
1	2	1.6375*	.314	.000	.7029	2.5721
	3	.8273	.331	.126	-.1579	1.8124
	4	-.2767	.343	.884	-1.2965	.7430
2	1	-1.6375*	.314	.000	-2.5721	-.7029
	3	-.8103	.314	.108	-1.7449	.1244
	4	-1.9142*	.327	.000	-2.8852	-.9432
3	1	-.8273	.331	.126	-1.8124	.1579
	2	.8103	.314	.108	-.1244	1.7449
	4	-1.1040*	.343	.030	-2.1237	-8.4228E-02
4	1	.2767	.343	.884	-.7430	1.2965
	2	1.9142*	.327	.000	.9432	2.8852
	3	1.1040*	.343	.030	8.423E-02	2.1237

*The mean difference is significant at the .05 level

CHAPTER V

DISCUSSION

This study has found after EMG data analysis of the golf swing before and after a simulated nine hole round of golf a significant amount of fatigue occurred in all muscles of all subjects collectively. Further data analysis revealed in all subjects, looking at each muscle specifically, the right abdominal oblique, left and right gluteals, and right and left erector spinae all showed a significant amount of fatigue. The only trunk muscle that did not show a significant amount of fatigue was the left abdominal oblique.

One possible reason for the decreased amount of fatigue in the left abdominal oblique compared to the others is the relationship between muscle length and fatigue. JR Potvin et al[9] performed a study on the effects of muscle kinematics on surface EMG amplitude and frequency during fatiguing dynamic contractions. According to this study, fatigue related shifts to lower EMG mean power frequency were more pronounced at shorter muscle lengths. In other words, a muscle that is actively reaching its most shortened position will display a greater amount of fatigue compared to a muscle that is passively shortening or actively lengthening.

During the motion of the golf swing, of the trunk muscles monitored, the only muscle that does not actively shorten is the left abdominal oblique. It begins actively elongating during the takeaway phase, returning to normal length in the forward swing-impact phase. Finally, during the follow-through, it is passively shortened due to the momentum from the forward swing. Since the left abdominal oblique minimally, if ever, produces an active concentric contraction, never actively reaching a shortened position, it will not experience a significant amount of fatigue.

The results for each individual revealed subjects 2 and 3 showed a significant amount of fatigue while 1 and 4 did not. Swing time analysis revealed subjects 1 and 4 had slower swing times while subjects 2 and 3 had faster swing times. These two findings are relevant to each other in that the subjects with the faster swing times were most likely using greater muscular forces in an effort to produce a faster and more powerful swing, thus hitting the ball further. As a result of this increased effort these subjects experienced greater fatigue.

JR Potvin et al[9] supports this theory in their study. They found that the largest EMG increases were observed at higher concentric joint velocities. They also found fatigue had a larger effect on force-generating capacity at these higher concentric joint velocities.

Limitations

This study could be improved upon by increasing the number of subjects analyzed. Stataticians usually recommend a subject pool of 100 subjects or larger to obtain an accurate estimate of reliability. Because this study consisted of a small sample size it's results are considered a rough estimate of actual reliability.[10] To increase the reliability a future study should increase its subject pool size.

Another limitation includes the procedure used to simulate the nine hole round of golf. Due to the distance between the practice field and the testing area a lag in time occurred before the subject could be re-tested. This amount of time remained under five minutes, however, difficulty was experienced with some subjects in reconnecting the EMG receiver. Because of this the time between the simulated round of golf and re-testing varied between each subject and may have been greater than five minutes for certain subjects. JR Doud et al[7] report that recovery of muscle fatigue occurred within 3-5 minutes. This may have affected the results of our study. If the time had been kept under 3-5 minutes, certain subjects may have shown greater amounts of fatigue, further supporting our results that fatigue occurs following a nine hole round of golf.

The EMG transmitters were connected to the subject's thigh using an adjustable belt. The subject also had EMG surface electrodes and a foot switch with leads connecting to the transmitters. These wires and the thigh belt may have limited the subjects from going through their normal golf swing motion.

CHAPTER VI

CONCLUSION

This research study appears to demonstrate a significant amount of fatigue following a simulated nine hole round of golf. This fatigue may be related to, if not a cause of low back injuries in golfers. Studies have reported muscular fatigue may lead to muscular compensation and ultimately lead to injuries. By focusing on the trunk muscles, this study has shown these muscles appear to fatigue following a simulated round of golf and may contribute to injuries. A conditioning program may help to increase a golfer's endurance thus decreasing the amount of fatigue experienced. This increased endurance may be beneficial in decreasing the number of golfing injuries.

An example of a pre-season conditioning program for golfers would consist of:

- Stretches focusing on: cervical spine, shoulders, forearms, wrists, hands, low back, hamstrings, quadriceps, and gastrocnemius-soleus
- Aerobic conditioning: 20-30 minutes 3-5 times/week of light to moderate activity (walking, biking)
- Golf conditioning: practice golf swings to improve technique and increase sport specific conditioning

A pre-game warm-up should also be performed throughout the season consisting of similar stretches to the above, warm-up swings and a short walk.

Recent literature has reviewed a variety of similar golf-specific conditioning programs. However, in order to find an effective conditioning program that will aid in reducing fatigue and therefore injury, further research in these areas needs to be performed.

Future studies directed at why the left oblique did not show significant fatigue may be beneficial. By monitoring only the left oblique during EMG analysis of the golf swing one can focus on it specifically. Looking at which times during each phase it is most active. Also how much activity is occurring throughout each phase. Similar studies may also improve upon their reliability and validity by increasing the consistency of the subjects' times between the simulated round and re-testing. This may be done by decreasing the distance between where the testing area and simulated round of golf are performed. Keeping the thigh belt connected to each subject's thigh while performing the simulated round may also help decrease the variability. Finally, monitoring and recording the exact times between the simulated round of golf and re-testing for each subject would be valuable supplemental information during the data analysis.

APPENDIX A

X EXPEDITED REVIEW REQUESTED UNDER ITEM 3 (NUMBER[S]) OF HHS REGULATIONS
___EXEMPT REVIEW REQUESTED UNDER ITEM ____ (NUMBER[S]) OF HHS REGULATIONS

UNIVERSITY OF NORTH DAKOTA HUMAN SUBJECTS REVIEW FORM FOR NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED PROJECTS INVOLVING HUMAN SUBJECTS

PRINCIPAL INVESTIGATOR: Dave Relling, Michelle Ballan, Katie Glessing, Nicole Garrett, Christine Wellner
TELEPHONE: (701) 777-4091 **DATE:** March 20, 1999
ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT: 501 N. Columbia Road, P.O. Box 9037, Grand Forks, ND 58202-9037
SCHOOL/COLLEGE: Medicine **DEPARTMENT:** Physical Therapy **PROPOSED PROJECT DATES:** April, 1999-April, 2000
PROJECT TITLE: EMG Analysis of Trunk Musculature Following a 9 Hole Round of Golf: The Fatigue Factor

FUNDING AGENCIES (IF APPLICABLE):
TYPE OF PROJECT (Check ALL that apply):

X NEW PROJECT ___ CONTINUATION ___ RENEWAL ___ DISSERTATION OR THESIS RESEARCH X STUDENT RESEARCH PROJECT

___ CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER: David Relling, MS, PT

PROPOSED PROJECT: ___ INVOLVES NEW DRUGS (IND) ___ INVOLVES NON-APPROVED USE OF DRUG ___ INVOLVES A COOPERATING INSTITUTION

IF ANY OF YOUR SUBJECTS FALL IN ANY OF THE FOLLOWING CLASSIFICATIONS, PLEASE INDICATE THE CLASSIFICATION(S):

___ MINORS (<18 YEARS) ___ PREGNANT WOMEN ___ MENTALLY DISABLED ___ FETUSES ___ MENTALLY RETARDED

___ PRISONERS ___ ABORTUSES X UND STUDENTS (>18 YEARS)

IF YOUR PROJECT INVOLVES ANY HUMAN TISSUE, BODY FLUIDS, PATHOLOGICAL SPECIMENS, DONATED ORGANS, FETAL MATERIAL, OR PLACENTAL MATERIALS, CHECK HERE

IF YOUR PROJECT HAS BEEN WILL BE SUBMITTED TO ANOTHER INSTITUTIONAL REVIEW BOARD(S), PLEASE LIST NAME OF BOARD(S):
Status: ___ Submitted; Date ________________ ___ Approved; Date ______________ ________Pending

1. ABSTRACT: (LIMIT TO 200 WORDS OR LESS AND INCLUDE JUSTIFICATION OR NECESSITY FOR USING HUMAN SUBJECTS.

There are nearly 25 million golfers in the US. The most common golf related injury reported by amateurs is low back pain. Injuries are most likely to occur during the golf swing. Golf injuries tend to result from overuse of the trunk musculature. Studies have shown fatigue may lead to improper body mechanics resulting in abnormal stresses and possible overuse injuries. For this reason, analyzing the muscle fatigue component of trunk musculature is essential to identifying fatigue as an injury risk factor. In reviewing the literature relatively few studies of this subject were found. The purpose of this study is to determine the fatigue component in trunk musculature following a round of golf through analysis of the swing.

We hypothesize that trunk musculature will show a significant amount of fatigue following a 9 hole round of golf. The results will attempt to provide information on establishing training and conditioning programs targeting trunk musculature. This information will be beneficial to physical therapists working with all levels of golfers, both in training and rehabilitation of low back injuries. Healthy human subjects are necessary to determine which muscles are active, when they are active, and muscle fatigability while performing the golf swing. **PLEASE NOTE:** Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate attach sections from your proposal (if seeking outside funding).

2. PROTOCOL: (Describe procedures to which humans will be subjected. Use additional pages if necessary.)

Subjects
The subject sample will consist of 10 male subjects, right hand dominant, from the University of North Dakota voluntarily recruited for this study. The subjects will be between the ages of 18-30 and will have no previous or existing trunk injuries. All

subjects will appear to be in good general health. The subject's average score for a nine hole round of golf will fall into the range of 40-50 strokes. All participants will sign appropriate human subject consent forms.

Procedure

The study will be conducted in the University of North Dakota physical therapy department and north intramural fields. Upon entering the facility the subjects will be given verbal instructions on the purpose and procedure of the study and then will be asked to sign a consent form. Self-adhesive EMG electrodes will be placed over the erector spinae, obliques, and gluteus maximus muscles bilaterally. Surface electrodes will be placed over pre-determined motor points of the above muscles. If necessary the skin will be shaved and cleansed with alcohol before attachment of the EMG electrodes to ensure adequate conduction. The EMG signals will be transmitted to a receiver unit, then fed into a computer for display and recording of data. Maximal voluntary contractions of the previously mentioned muscles will be measured using manual muscle testing techniques administered by the testers. Muscle activity recorded during the maximal voluntary contraction will be considered as 100% activity level. This procedure is done to normalize the EMG data for later analysis.

The subject will be allowed 5 warm-up swings with electrodes attached and transmitter unit on thigh to ensure comfort and unobstructed swing. Each subject will take 5 normal golf swings with a driver, hitting a practice ball into a net, to obtain initial baseline EMG and motion analysis data. The subject will proceed to walk with testers __ yards to the north intramural fields to perform repeated swings. Swings will consist of 1 swing with a driver, 2 with a 5 iron and 2 with a putter. This pattern will be repeated 9 times to simulate a nine hole round of golf. All swings will make contact with a real golf ball. Immediately following this simulated round the subjects will walk with the testers back to the physical therapy department to complete the collection of EMG muscle activity data. The subject will again take 5 swings with a driver, making contact with a plastic ball, to collect final data.

Data collection will consist of measurements of muscle activity and fatigue around the trunk and pelvis. Statistical analysis of the mean activity of each monitored muscle will be performed prior to and following the simulated round of golf. The EMG data collected during the experimental trials will be expressed as a percentage of the EMG activity recorded during the maximal voluntary contraction prior to the experimental trials. Data collected before and after the simulated nine hole round of golf will be compared to determine if muscle fatigue has occurred.

3. **BENEFITS:** (Describe the benefits to the individual or society.)

Possible benefits of this study will include obtaining information on the amount of fatigue experienced by trunk musculature during a 9 hole round of golf. By identifying which muscles and to what extent they fatigue, training and conditioning programs can be developed to help increase endurance. By increasing muscular endurance it is possible to decrease the likelihood of muscle compensation patterns that may lead to faulty swing mechanics which in turn increase the risk of injury.
By establishing data on trunk muscle fatigability and trunk and pelvis motion before and after a 9 hole round of golf we will provide information that can be used clinically in the treatment of patients and for further research endeavors.

4. **RISKS:** (Describe the risks to the subject and precautions that will be taken to minimize them. The concept of risk goes beyond physical risk and includes risks to the subject's dignity and self-respect, as well as psycho-logical, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, including plans for final disposition or destruction, debriefing procedures, etc.)

Physical risks to the subjects of this study are minimal to moderate. EMG poses no risk to subjects. Muscle strains are a possible risk to the subjects, but should be minimal due to the ability and health of the golfers. Each subject will be given a warm-up period which will also decrease the risk of muscle strains.

All data will be collected and remain confidential throughout and following the study. Subjects will be assigned code numbers to ensure confidentiality and eliminate the use of their names for data collection purposes. Participation in this study is voluntary and subjects are free to withdraw at anytime for any reason without fear of retribution. Data will be kept for three years in the UND Physical Therapy Department.

5. **CONSENT FORM:** A copy of the **CONSENT FORM** to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no **CONSENT FORM** is to be used, document the procedures to be used to assure that infringement upon the subject's rights will not occur.

Describe where signed consent forms will be kept and for what period of time.

A copy of the consent form is attached. Signed consent forms will be kept by David Relling for three years in the UND Physical Therapy Department.

6. For **FULL IRB REVIEW** forward a signed original and thirteen (13) copies of this completed form, and where applicable, thirteen (13) copies of the proposed consent form, questionnaires, etc. and any supporting documentation to:

Office of Research & Program Development
University of North Dakota
Grand Forks, North Dakota 58202-7134

On campus, mail to: Office of Research & Program Development, Box 7134, or drop it off at Room 105 Twamley Hall.

For **EXEMPT** or **EXPEDITED REVIEW** forward a signed original and a copy of the consent form, questionnaires, etc. and any supporting documentation to one of the addresses above.

The policies and procedures on Use of Human Subjects of the University of North Dakota apply to all activities involving use of Human Subjects performed by personnel conducting such activities under the auspices of the University. No activities are to be initiated without prior review and approval as prescribed by the University's policies and procedures governing the use of human subjects.

SIGNATURES:

Principal Investigator	Date
Project Director or Student Adviser	Date
Training or Center Grant Director	Date

(Revised 3/1996)

STUDENT RESEARCHERS: As of June 4, 1997 (based on the recommendation of UND Legal Counsel) the University of North Dakota IRB is unable to approve your project unless the following "Student Consent to Release of Educational Record" is signed and included with your "Human Subjects Review Form."

STUDENT CONSENT TO RELEASE OF EDUCATIONAL RECORD[1]

Pursuant to the Family Educational Rights and Privacy Act of 1974, I hereby consent to the Institutional Review Board's access to those portions of my educational record which involve research that I wish to conduct under the Board's auspices. I understand that the Board may need to review my study data based on a question from a participant or under a random audit. The study to which this release pertains is EMG Analysis of Trunk Musculature Following a 9 Hole Round of Golf: The Fatigue Factor.

I understand that such information concerning my educational record will not be released except on the condition that the Institutional Review Board will not permit any other party to have access to such information without my written consent. I also understand that this policy will be explained to those persons requesting any educational information and that this release will be kept with the study documentation.

Date Signature of Student Researcher

[1]Consent required by 20 U.S.C. 1232g.

INFORMATION AND CONSENT FORM

TITLE: EMG Analysis of Trunk Musculature Following a 9 Hole Round of Golf: The Fatigue Factor.

You are being invited to participate in a study conducted by Dave Relling, a physical therapy instructor at the University of North Dakota, Michelle Ballan, Nicole Garrett, Katie Glessing and Christine Wellner, physical therapy students at the University of North Dakota. The purpose of this study is to determine the amount of fatigue trunk musculature experiences following a nine hole round of golf through analysis of the golf swing. The results will attempt to provide information on establishing training and conditioning programs targeting trunk musculature, especially on increasing endurance to prevent muscle compensation patterns that result from muscle fatigue. They will also provide information that will help reduce and prevent golf-related injuries. Only healthy subjects will be used to participate in this study.

You will be asked to take 10 total swings with a driver while connected to the EMG equipment. Five swings will be taken before and after you play a simulated 9 hole round of golf. During the round you will take 1 swing with a driver, 2 with a 5 iron and 2 putts and all swings will be with real golf balls. This sequence will be repeated 9 times to simulate an actual round of golf. You will be given a few minutes to warm up before performing the actual trials.

This study will take approximately two hours of your time. You will be asked to report to the University of North Dakota physical therapy department at the designated time. We will record your age and gender for data analysis purposes. During the experiment we will be recording the amount of muscle activity during the golf swing.

The process of physical performance testing always involves some degree of risk, but the investigators in this study feel that the risk of injury or discomfort is minimal. In order for us to record the muscle activity, we will be placing thirteen adhesive electrodes on the skin of your trunk and pelvis. Shaving of the hair from the area where the electrode is placed may be necessary. These electrodes only record information from your muscles and joints, they do not stimulate the skin. The amount of exercise that you will be asked to perform will be minimal to moderate.

Your name will not be used in any reports of this study's results. Any information that is obtained in connection with this study that can be identified with you will remain confidential and will only be disclosed with your permission. A number known only to the investigator will identify the data. You or the investigator may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue or any other symptoms that may be detrimental to your health. Your decision on whether or not to participate will not prejudice your current or future relationship to the physical therapy department or the University of North Dakota. You are also free to discontinue participation at any time without consequences.

The investigators involved are available to answer any current or future questions you have concerning this study. Questions may be addressed to Dave Relling or any one of the other investigators at (701) 777-2831. A copy of this consent form is available to all participants in the study. Signed consent forms will be kept by Dave Relling in the University of North Dakota Physical Therapy Department for 3 years.

In the event that this research activity results in a physical injury, medical treatment will be available, including first aid, emergency treatment and follow up care as it is to any member of the general public. You and your third party payer must provide payment for any such treatment, if applicable.

ALL OF MY QUESTIONS HAVE BEEN ANSWERED AND I AM ENCOURAGED TO ASK ANY QUESTIONS THAT I MAY HAVE CONCERNING THIS STUDY IN THE FUTURE. MY SIGNATURE INDICATES THAT, HAVING READ THE ABOVE INFORMATION, I HAVE DECIDED TO PARTICIPATE IN THE RESEARCH PROJECT.

I have read all of the above information and willingly agree to participate in this study as explained to me by Dave Relling, Michelle Ballan, Nicole Garrett, Katie Glesing or Christine Wellner.

____

Participant's Signature Date

____

Witness (not the investigator) Date

REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW
University of North Dakota Institutional Review Board

DATE: April 7, 1999 **PROJECT NUMBER:** IRB-9904-205

NAME: Dave Relling, Michelle Ballan, Katie Glessing, Nicole Garrett, Christine Wellner **DEPARTMENT/COLLEGE:** Physical Therapy

PROJECT TITLE: EMG Analysis of Trunk Musculature Following a 9 Hole Round of Golf: The Fatigue Factor

The above referenced project was reviewed by a designated member for the University's Institutional Review Board on 4-8-99 and the following action was taken:

☒ Project approved. **EXPEDITED REVIEW** No. 4.
Next scheduled review is on April 2000.

☐ Project approved. **EXEMPT CATEGORY** No. ________. No periodic review scheduled unless so stated in the Remarks Section.

☐ Project approved **PENDING** receipt of corrections/additions. These corrections/additions should be submitted to ORPD for review and approval. **This study may NOT be started UNTIL final IRB approval has been received.** (See Remarks Section for further information.)

☐ Project approval **deferred. This study may not be started until final IRB approval has been received.** (See Remarks Section for further information.)

☐ Project **denied.** (See Remarks Section for further information.)

REMARKS: Any changes in protocol or adverse occurrences in the course of the research project must be reported immediately to the IRB Chairperson or ORPD.

PLEASE NOTE: Requested revisions for student proposals MUST include adviser's signature.

cc: David Relling, Adviser
Dean, Medical School

John P. Madden 4-8-99

Signature of Designated IRB Member
UND's Institutional Review Board

Date

If the proposed project (clinical medical) is to be part of a research activity funded by a Federal Agency, a special assurance statement or a completed 310 Form may be required. Contact ORPD to obtain the required documents.

(1/98)

APPENDIX B

Paired T-Test of Left Oblique for all subjects and swings

Paired Samples Test

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	FREQ1 - FREQ2	1.8275	17.2689	6.1055	.299	7	.773

Paired T-Test of Right Oblique for all subjects and swings

Paired Samples Test

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	FREQ1 - FREQ2	14.6834	14.6446	5.1777	2.836	7	.025

Paired T-Test of Left Gluteal for all subjects and swings

Paired Samples Test

		Paired Differences			t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	FREQ1 - FREQ2	18.5084	14.3716	5.0811	3.643	7	.008

Paired T-Test of Right Gluteal for all subjects and swings

Paired Samples Test

		Paired Differences			t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	FREQ1 - FREQ2	16.3721	12.4351	4.3965	3.724	7	.007

Paired T-Test for the Left Erector for all subjects and swings

Paired Samples Test

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	FREQ1 - FREQ2	8.2001	7.4169	2.6223	3.127	7	.017

Paired T-Test for Right Erector for all subjects and swings

Paired Samples Test

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	FREQ1 - FREQ2	13.5057	12.0205	4.2499	3.178	7	.016

Paired T-Test of Subject #1 for Pre-Round and Post-Round Median Frequency

Paired Samples Test

		Paired Differences			t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	FREQ1 - FREQ2	11.2619	17.7974	5.1377	2.192	11	.051

Paired T-Test of Subject #2 for Pre-Round and Post-Round Median Frequency

Paired Samples Test

		Paired Differences			t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	FREQ1 - FREQ2	7.1493	6.0556	1.7481	4.090	11	.002

Paired T-Test of Subject #3 for Pre-Round and Post-Round Median Frequency

Paired Samples Test

		Paired Differences			t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	FREQ1 - FREQ2	22.9314	10.9936	3.1736	7.226	11	.000

Paired T-Test of Subject #4 for Pre-Round and Post-Round Median Frequency

Paired Samples Test

		Paired Differences			t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	FREQ1 - FREQ2	7.3888	12.8960	3.7227	1.985	11	.073

Paired T-Test of Pre-Round and Post-Round Median Frequency of all subjects combined

Paired Samples Test

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	FREQ1 - FREQ2	12.1829	13.8555	1.9999	6.092	47	.000

REFERENCES

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